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# EFFECT OF SILICA FUME ON RHEOLOGY AND MECHANICAL PROPERTY OF SELF COMPACTING CONCRETE

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**ABSTARCT**

*The usage of an extensive group of industrial mineral residues (silica fume and fly ash) and other products significantly increases the rheological performance of concrete. This research is supposed to take a look at Rheology and Strengthened Properties of Self Compacting Concrete with Silica fume. This examination commenced with 4 groups of Self Compacting Concrete changed with diverse probabilities of Silica fume (5%, 10%,15%, and 20%). The rheological properties of self-compacting concrete are investigated experimentally using the slump flow diameter, the U box test, the V funnel test, and the L box test. Compressive strength and flexural strength are the strengthened properties experimentally examined.*

*In this study, we observed the suitable percent of silica fume, which offers advanced rheological characteristics of Self Compacting Concrete as equated to Conventional Self Compacting Concrete. Our experimental results show, by the replacing 15% of silica fume with the weight of cement will increase both Rheological Properties and strengthened Properties of SCC.*

**Keywords:** Mechanical Properties, Rheological Properties, Self Compacting Concrete, Silica fume

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## 1. INTRODUCTION

Since the inception concrete has undergone a major revolution, particularly to improve concrete strength. But in recent times, other properties such as durability and workability of the concrete are also considered essential. Self Compacting Concrete (SCC) is a special category of concrete that flows on the influence of its mass and spreads in the form without the necessity of external vibration.

Several tactics have been used to develop SCC. One of the most frequently adopted technique is by addition of a Superplasticizer. The most important goal of the superplasticizer is to boom the flowability of concrete without distressing the mechanical property. However, it had been experiential in some of the cases segregation may occur that vitiates the concrete quality. Hence by the adding of Viscosity Modifying Agent (VMA) helps the concrete to make more stable and cohesive, which limits the segregation. Another tactic is to increase cement significantly. However, increasing cement leads to increases in the outlay of construction and additionally increases the hassle of shrinkage owing to the escalation in heat of hydration of cement. To ensure sustainable development, it is mandatory to substitute the cement with mineral admixtures. Since silica fume is a finer particle it fills the voids in the concrete.

Concrete produced with silica fume appears to have thixotropic behavior. Under static condition concrete produced with silica fume, they have vicious performance. However, they come to be liquefied as soon as the pressure is implemented on them. With silica fume accumulation, the viscosity of concrete increases. Which in turn helps to lessen the segregation of concrete.

The idea of the research is to inspect the properties of silica fume on the rheological and hardened properties of SCC. The rheological test of SCC with Silica fume was performed to discover the proportion of Silica fume required to gain the equal viscosity value as traditional SCC. Next, the hardened properties of SCC are studied to find the ideal percentage of silica fume.

## 2. EXPERIMENTAL PROGRAM

This investigational program was steered in two parts. In the primary part of the program, the rheological characteristics of SCC with various percentages of silica fume (SF) is evaluated. The strengthened properties of the prepared samples were determined in the subsequent part for a period of 7 and 28 days.

### 2.1. Materials

Ordinary Portland Cement as per Indian Standards (IS – 12269) grade 53 is used as a binding material. SIKA STABILIZER 4r is used as VMA. The Chemical belongings of cement and admixtures are given in table - 1.

Naturally occurring fine aggregate is used confirming to Indian Standards (IS 383 – 2016) zone – III with specific gravity 2.73, fineness modulus 2.23, and coarse aggregate having the utmost size of 10 mm with a specific gravity of 2.67 and water absorption 1.4% was used.

**Table 1** Chemical Properties of the Materials

| | **Cement** | **Silica Fume** | **VMA** |
|---|---|---|---|
| $C_3S$ (%) | 60 | - | - |
| $C_2S$ (%) | 12 | - | - |
| $C_4AF$ (%) | 9 | - | - |
| $C_3A$ (%) | 9 | - | - |
| $SiO_2$ (%) | 21.5 | 85 | - |
| $Fe_2O_3$ (%) | 1.8 | - | - |
| $Al_2O_3$ (%) | 4.8 | - | - |
| CaO (%) | 63 | - | - |
| Density | 3.15 | 2.22 | 1.02 |
| $cl^-$ (%) | - | - | < 0.1 |
| Baline ($cm^2/g$) | | - | - |
| pH | - | - | 8 |

## 2.2. Mix Proportioning

A general of five combos was calculated taking a water/binder (W/B) fraction equal to 0.35 and a whole binder content material of 520 kg/m$^3$. Concrete mixes incorporate cement blends in which cement is supplemented by a certain amount of mineral admixture. The replacement of SF is 5%, 10%, 15%, and 20%. The substitute percent of VMA is 0.10%, 0.15%, 0.20%, and 0.25% with the aid of using the weight of the binder. Concrete blend proportions are concise in table 2.

**Table 2** Concrete Mix Proportion

| Mixture Name | W/B (%) | Silica Fume (%) | VMA (%) | Binder (kg/m$^3$) | Sand (kg/m$^3$) | Gravel (kg/m$^3$) |
|---|---|---|---|---|---|---|
| Control | 0.35 | 0 | 0 | 520 | 890 | 900 |
| SF5 | 0.35 | 5 | 0.10 | 520 | 890 | 900 |
| SF10 | 0.35 | 10 | 0.15 | 520 | 890 | 900 |
| SF15 | 0.35 | 15 | 0.20 | 520 | 890 | 900 |
| SF20 | 0.35 | 20 | 0.25 | 520 | 890 | 900 |

## 2.3. Preparation of Specimen

The timing of the concrete blending course was saved consistently to present the same homogeneousness and uniformity for all of the concrete blends. During the preliminary minute, all the combination and binder blended with the use of a standard mixer. Then water was added to the mixture and mixed for an additional minute. VMA has introduced to the mixture afterward and the concrete was mixed for an extra 3 minutes.

After the mixing course was finished, trials were executed to determine the rheological property of concrete by slump diameter, V-funnel flow, U box test, and L box test. Cubes of size 150 x 150 x 150 mm were castoff to evaluate the crushing strength and Unreinforced concrete beam samples of 150 x 150mm and 450mm depth were used to determine the bending strength.

## 2.4. Test Methods

The slump trial for SCC was conducted as prescribed in EFNARC [12]. In this test, an abridged cone was positioned on an even plate, filled with SCC, and the cone is raised upwards. The SCC diameter is defined in two ways and the flow diameter is concluded as the common of both. The V funnel flow trial was conducted as prescribed in [12], the funnel is full of concrete completely and lets in the concrete to glide out with the aid of using establishing the bottom. The flow period (t), in seconds, was measured. To determine the passing functionality of concrete in restrained spaces, the L box test is used. The apparatus is kept in a smooth level base. The perpendicular portion of the box is filled with SCC and left ideal for a minute. Height $H_1$ and $H_2$ are measured and the ratio of $H_2/H_1$ is reported as Passing Ability[12].

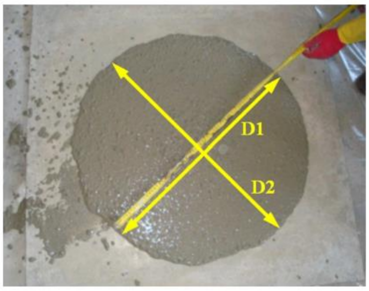


**Figure 1** Slump Flow test

To evaluate the filling and passing capacity of the freshly prepared SCC, the U container check was performed. The U box was positioned on a leveled surface and ensured by a spirit level. After moisturizing the inner surface, concrete is filled in the left compartment to the top without compaction and excess concrete is strike off, allow the concrete right side of the compartment. After completion of concrete flow, measure the height of the concrete surface at both compartments $h_1 - h_2$ as filling ability[12].

**Figure 2.** L box test

**Figure 3.** U box test

## 3. RESULTS AND DISCUSSION

### 3.1. Fresh Properties

The test results of various fresh characteristics of concrete blends are represented in table 3. In general, all the new combinations comply with EFNARC guidelines with a slump diameter greater than 60cm[12]. These findings suggest that the incorporation of silica fume initiates a reduction in the slump flow diameter as a partial weight substitution of the cement.

Regards to the V funnel test in table 3 shows that the control mix has the least time in seconds to unfilled the funnel. However, with the buildup of silica fume and the VMA, the time it takes for concrete mixes to fill, the funnel is increased. This is due to the increase in viscosity mostly with the addition of VMA and fume silica. Also, fig 1 represents the results of SCC with silica fume and VMA.

The L box test in table 3 shows that the proportion of $H_2/H_1$ declines with the addition of the dosage of silica fume and VMA. This is primarily because of the rise in viscosity mostly with the addition of VMA and fume silica. Also, Fig 2 indicates the results of SCC with silica fume and VMA.

Concerning the U container test, table 3 indicates the overall performance of SCC with Silica fume and VMA became higher in comparison to govern mixes. This observation illustrates that the accumulation of silica fume makes the concrete mixture is more viscous.

Based on EFNARC guidelines (Slump diameter greater than 60 cm, Proportion of $H_2/H_1$ extra than 0.80, and V funnel time much less than or equals to 14sec), our studies suggests that concrete combos with SF5, SF10, and SF15 reached the necessities to stay indexed as Self Compacting Concrete.

**Table 3** Fresh Properties of SCC

| Mixture Name | Slump flow diameter (cm) | V funnel test time (s) | L box test $H_2/H_1$ ratio | U box test $h_2 - h_1$ (cm) |
|---|---|---|---|---|
| Control – 1 | 65.8 | 11 | 0.89 | 21 |
| Control – 2 | 66.3 | 12 | 0.88 | 19 |
| Control - 3 | 64.8 | 12 | 0.90 | 19 |
| Control - Average | 65.6 | 11.6 | 0.89 | 19.7 |
| SF5 - 1 | 64.2 | 12 | 0.86 | 22 |
| SF5 – 2 | 63.9 | 13 | 0.84 | 21 |
| SF5 – 3 | 65.1 | 15 | 0.84 | 22 |
| SF – Average | 64.4 | 13.3 | 0.85 | 21.6 |
| SF10 – 1 | 62.8 | 13 | 0.80 | 23 |
| SF10 – 2 | 61.6 | 14 | 0.80 | 25 |
| SF10 – 3 | 63.9 | 14 | 0.82 | 25 |
| SF10 – Average | 62.7 | 14 | 0.81 | 24.3 |
| SF15 – 1 | 60.5 | 15 | 0.81 | 27 |
| SF15 – 2 | 58.6 | 13 | 0.80 | 26 |
| SF15 – 3 | 62.0 | 13 | 0.80 | 27 |
| SF15 - Average | 60.4 | 13.6 | 0.80 | 26.6 |
| SF20 - 1 | 59.2 | 18 | 0.78 | 32 |
| SF20 - 2 | 57.6 | 20 | 0.76 | 32 |
| SF20 - 3 | 60.1 | 21 | 0.76 | 30 |
| SF - Average | 58.9 | 19.6 | 0.77 | 31.3 |
| *Acceptance Criteria for SCC based on EFNARC* | | | | |
| SCC | 60 – 80 | 6 – 14 | ≥0.80 | 0 - 30 |

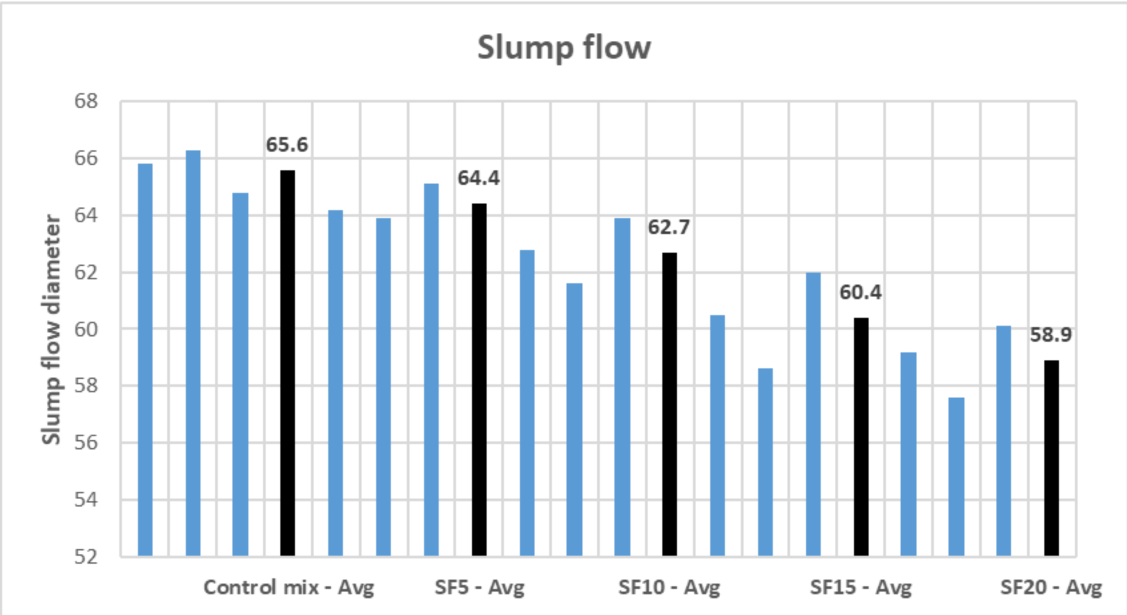


**Figure 4** Slump flow result

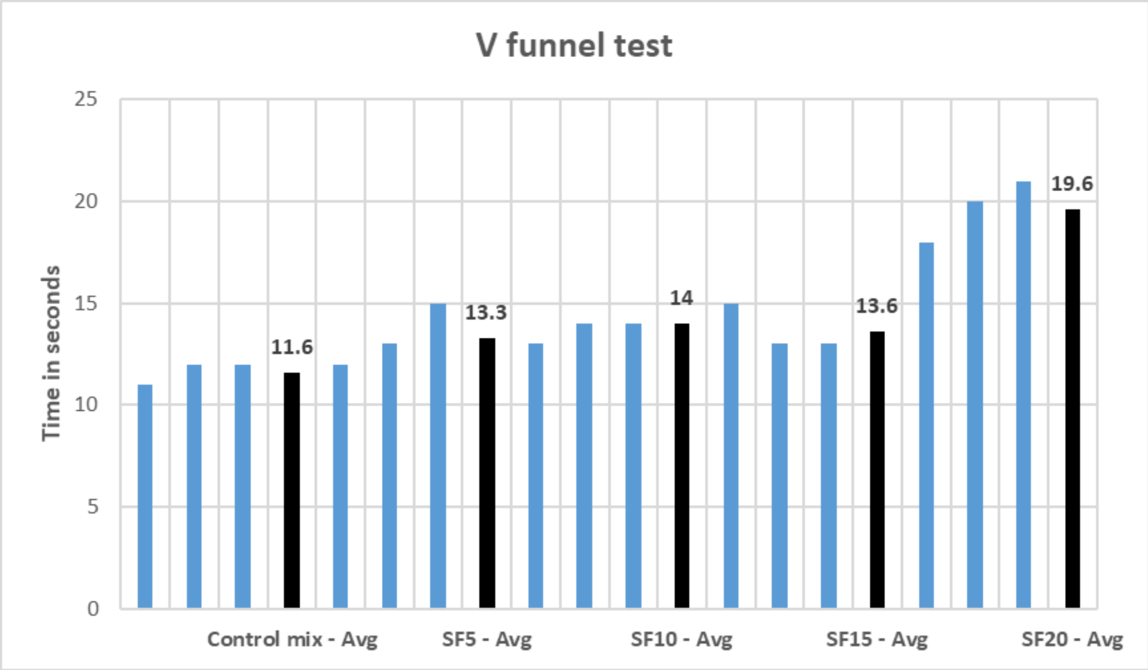


**Figure 5** V funnel test result

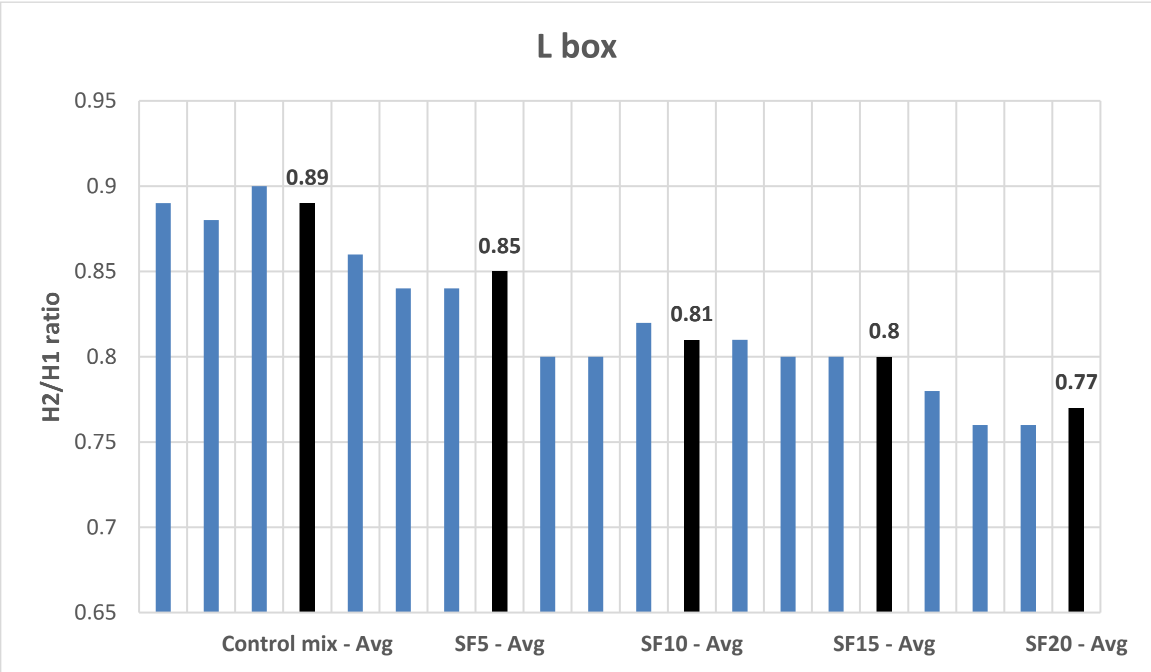


**Figure 6** L box test result

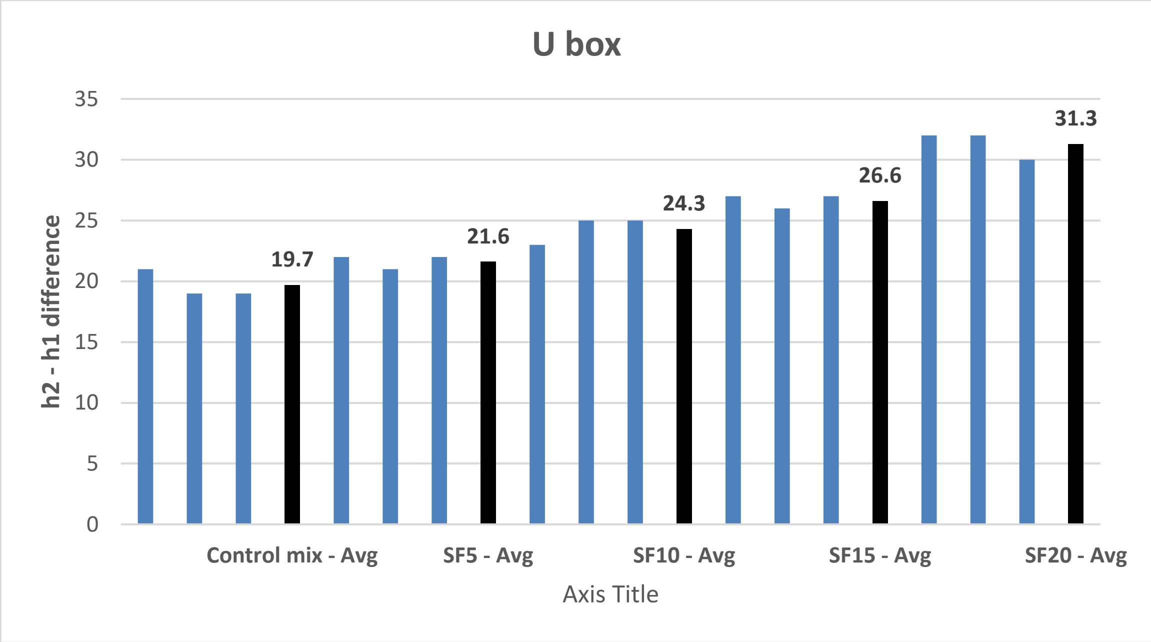


**Figure 7** U box test result

## 3.2. Hardened Properties of SCC

To measure the actual quality of the concrete, crushing strength is examined. To compare the crushing strength, 3 cubes of length 150x150x150 mm had been forged for 7 and 28 days of curing age. The crushing strength and bending strength development of SCC's are presented in table 4. A common of 3 specimens were cast for every mechanical characteristic. Experimental research display the control mixture at 7 days is 33.1 MPa and it will increase to 50.5 MPa at 28 days.

From table 4, the SF20 represents the first-rate mechanical belongings of SCC with crushing energy of 69.9 MPa and bending strength surpasses 9 MPa. This improvement in the concrete mixture is attained by the high pozzolanic action of SF.

**Table 4** Hardened Properties of SCC

| Mixture Name | Crushing strength (MPa) | | Bending Strength (MPa) |
|---|---|---|---|
| | 7 day | 28 days | |
| Control – 1 | 32.8 | 50.3 | 8.0 |
| Control – 2 | 33.1 | 51.2 | 7.6 |
| Control – 3 | 33.5 | 49.9 | 8.2 |
| Control - Average | 33.1 | 50.5 | 7.9 |
| SF5 - 1 | 42 | 60.1 | 8.3 |
| SF5 – 2 | 44.8 | 62.2 | 8.2 |
| SF5 – 3 | 43.9 | 62.8 | 8.0 |
| SF – Average | 43.6 | 61.7 | 8.2 |
| SF10 – 1 | 45.2 | 63.5 | 8.6 |
| SF10 – 2 | 44.8 | 63.0 | 8.8 |
| SF10 – 3 | 44.5 | 62.1 | 8.5 |
| SF10 – Average | 44.8 | 62.8 | 8.6 |
| SF15 – 1 | 46.3 | 66.3 | 9.1 |
| SF15 – 2 | 45.1 | 65.8 | 9.1 |
| SF15 – 3 | 44.9 | 66.1 | 9.0 |
| SF15 - Average | 45.4 | 66.1 | 9.1 |
| SF20 - 1 | 46.8 | 69.5 | 9.2 |
| SF20 - 2 | 47.3 | 70.3 | 9.1 |
| SF20 - 3 | 47.8 | 70.1 | 9.1 |
| SF - Average | 47.3 | 69.9 | 9.1 |

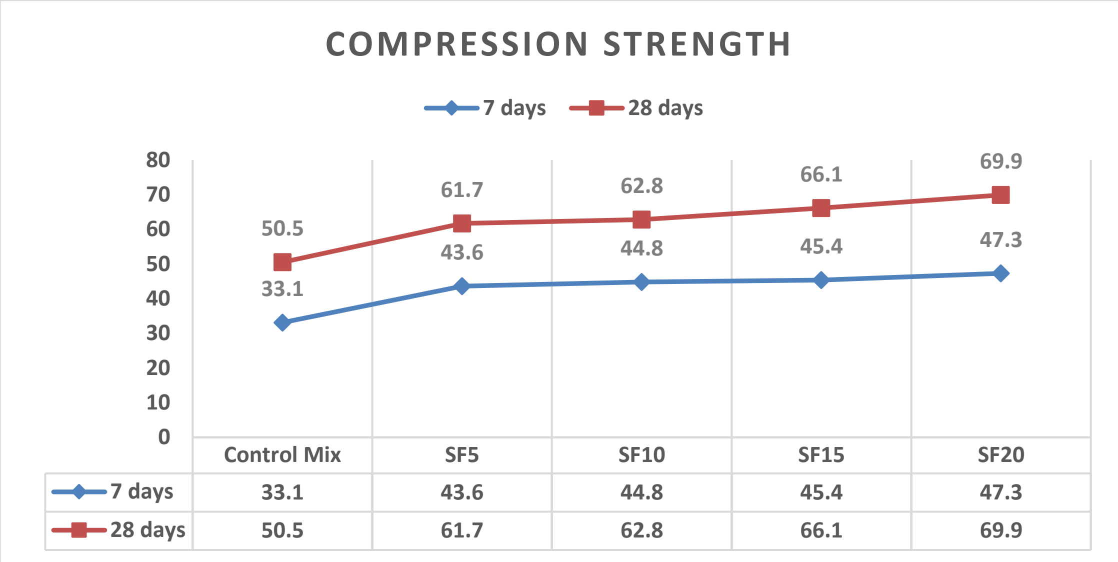


**Figure 8** Compression test result

20% of Silica fume (SF20) displayed the crushing strength booms withinside the order of 34% and 36% in comparison to the control mixture at 7 and 28 days correspondingly. And also 20% Silica fume (SF20) displays improvement in flexural strength significantly. But, as deliberated withinside the rheological belongings SF20 does now no longer meet the duty of SCC the mixes SF5, SF10, and SF15 meet the requirement of SCC. Compared to the control mixture 15% of Silica fume (SF15) displays an increase in compressive strength by 32% compared and also flexural strength surpasses 9MPa. It has also been observed SF20 mixture has less tendency towards segregation. Hence, the experimental results from table 3 and table 4 indicate the ideal utilization percentage of silica fume is 15%.

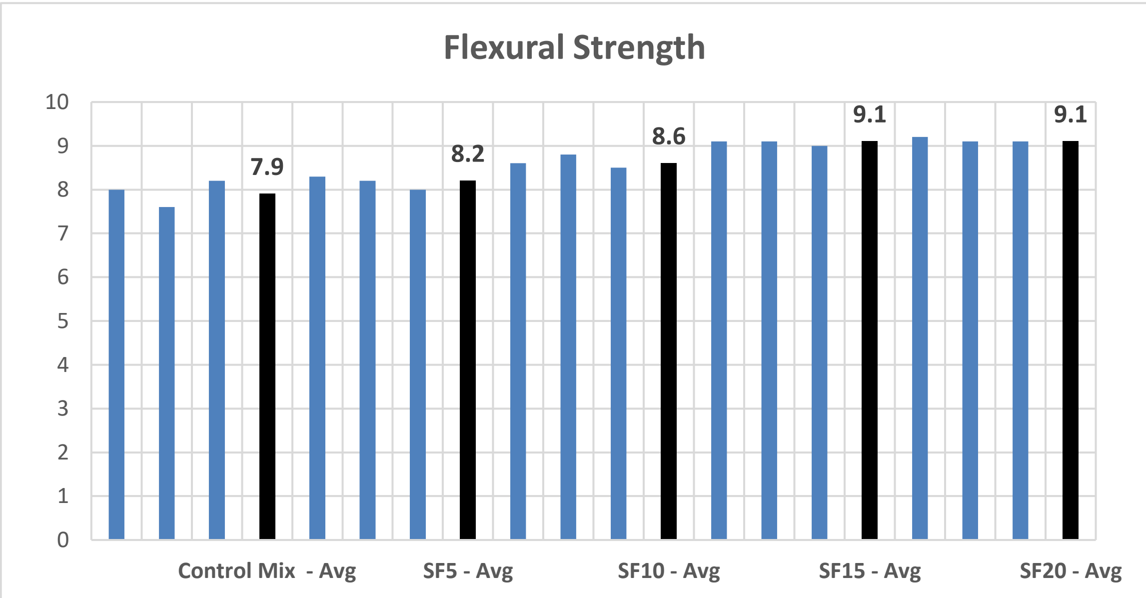


**Figure 9** Flexural Strength test result

## 4. CONCLUSION

Based on the suggestions of EFNARC, from our experimental work concrete combinations of SF5, SF10, and SF15 assembly are obliged to be categorized as Self Compacting Concrete. By the addition of silica fume, more than 15% affects the rheological traits of SCC. Since the Silica

fume, is a finer element it creates a concrete mixture more cohesive and denser and it limits the segregation. In a hardened state, the performance of SCC with 20% utilization Silica fume shows a greater development in crushing strength and bending strength properties.

Our experimental results show silica fume can be utilized up to 15% without affecting the rheology and mechanical characteristics of SCC's. Further the addition of Silica fume results in the declination of rheology belongings which in flip influences the stableness and filling capacity.

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